Regional Carbon Sequestration Partnerships – Annual Review Meeting

ARRA Site Characterization Projects – Characterization of the Triassic Newark Basin of Southeastern New York /Northern New Jersey

October 6, 2010

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October 5-7, 2010 • Sheraton Station Square • Pittsburgh, Pennsylvania

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- **Acknowledgment**: This material is based upon work supported by the Department of Energy [National Energy Technology Laboratory] under Award Number DE-FE0002352 and Contract No. 18131 from the New York State Energy Research & Development Authority [NYSERDA].

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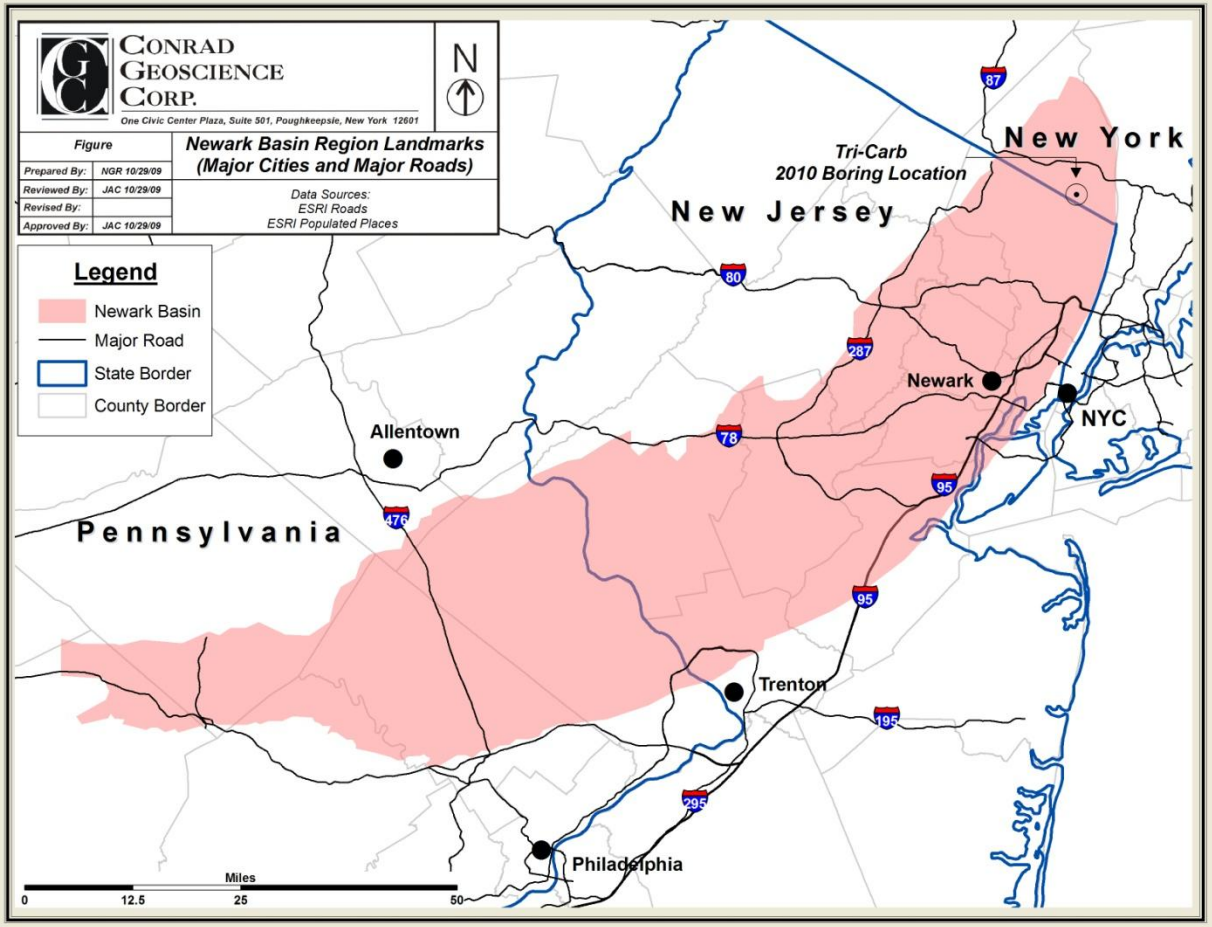
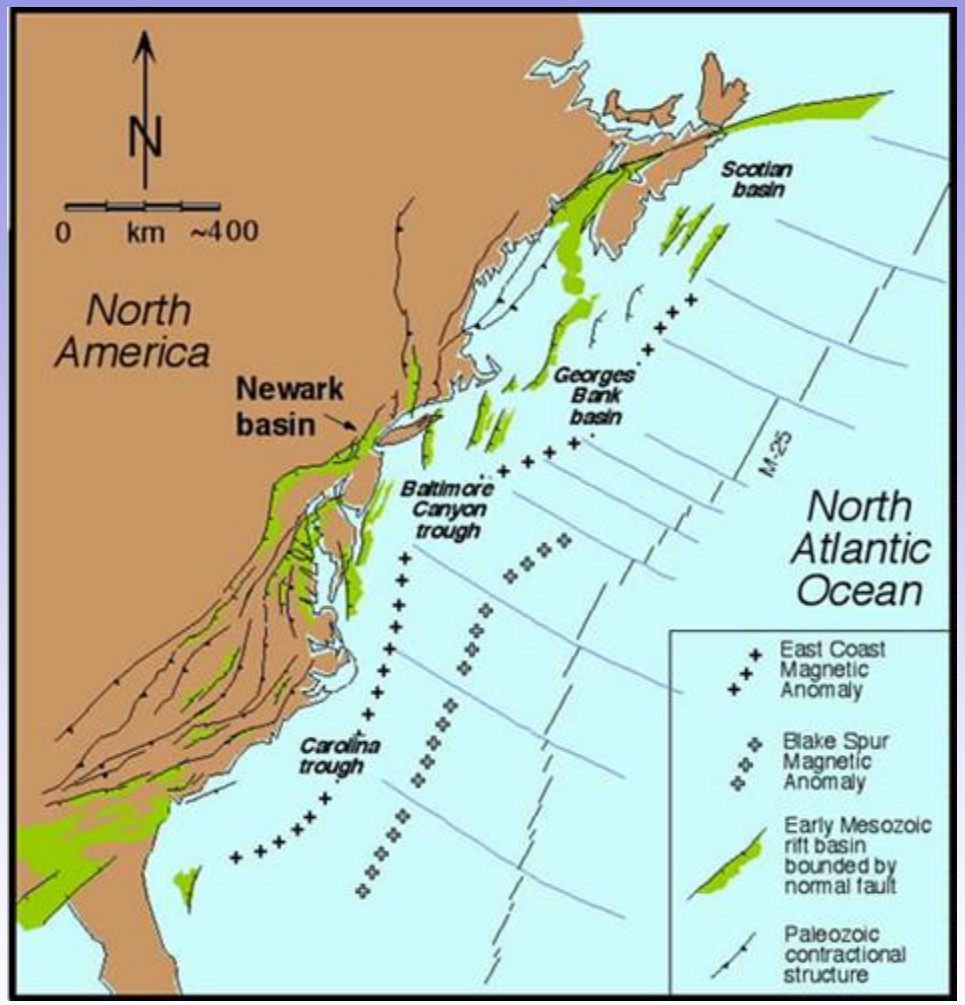
Physiogeographic Setting of the Newark Basin



- Newark Basin stretches from Rockland County, New York, southwest across northern New Jersey, and into southeastern Pennsylvania (140 miles long by 32 miles wide)
- Geographic extent ~ 2,700 square miles
- Merges into the Gettysburg Basin
- The Newark Basin is in close proximity to large population areas and a heavily industrialized section of the country (28 MM tons/year CO_2 in closest NY/NJ counties)
- Other potential geologic sequestration options are either offshore or well inland west of the Allegheny Front

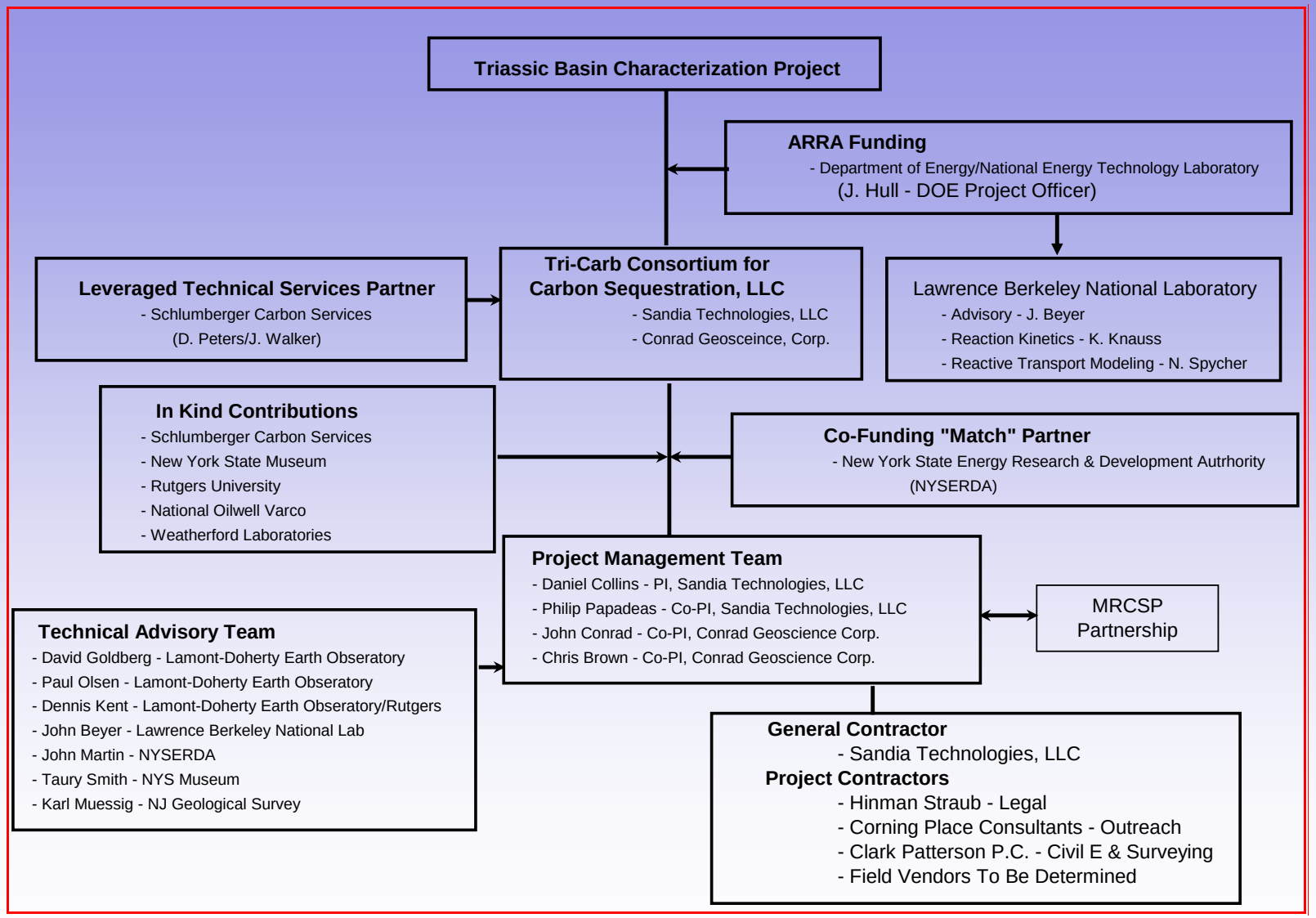
One of a Series of Basins along Eastern North America



Withjack et al., 1998

- Includes both "exposed" and "buried" basins of Jurassic-Triassic Age (Newark Basin is exposed) and offshore basins
- Formed by the "breakup" & separation of North/South America from Europe and Africa
- Basins generally set up by a border fault (western)
- Sediment infilled the basin from adjoining areas

Project Organization



Project Objectives

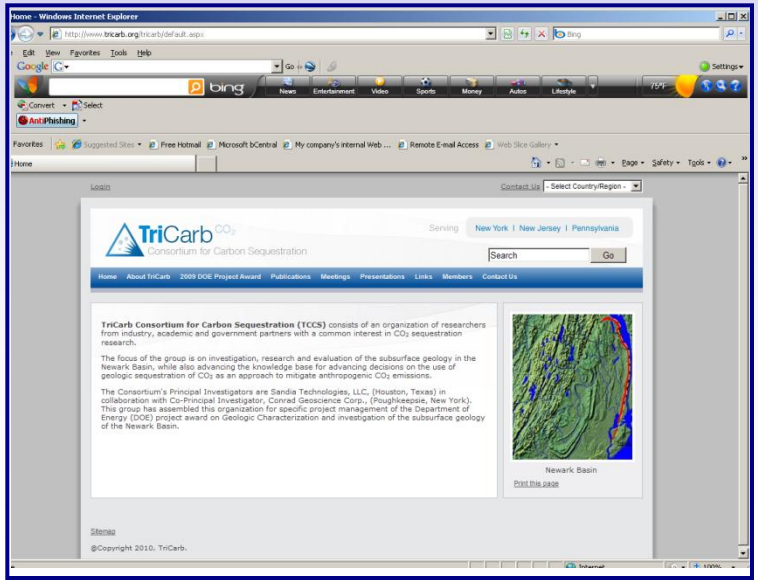
- Demonstrate that geologic sequestration of CO_2 offers an effective and viable large-scale mitigation approach to managing greenhouse gas emissions from industrial sources in the northeastern United States; and
- Create meaningful near-term and long-term employment, building and initiating the foundation for a CCS industry using the Newark Basin geologic formations

Phase 1 - Pre-Operational Site Characterization and Permitting (In Progress)

- Task 1.1 – Project Management/Planning & Outreach
- Task 1.2 – Finalize Agreements
- Task 1.3 – Obtain Environmental Permits & Well Drilling Approval
- Task 1.4 – Compile Existing Data & Develop Geological Model(s)

Task 1.1.2 – Planning & Reporting
Includes Public Outreach –
Corning Place Consultants/Conrad Geoscience Corp.

- Developed Outreach & Education Materials
  - Brochures/Packet and FAQ Sheet –Developed Stakeholders Project "Rollout" Plan (State/Local Electeds/Civic Leaders/Educators/Public
  - Timed to Well Permit Application submittal(s) to New York Sate Department of Environmental Conservation (NYSDEC)
- Created www.tricarb.org Site
  - Project Information
  - Online GIS Mapping Interface



Outreach Packet for Meetings With Stakeholders

Task 1.3 Obtain Environmental Permits & Well Drilling Approval

- New York State Department of Environmental Conservation (NYSDEC) – Stratigraphic Test Well
  - Division of Mineral Resources regulates all stratigraphic wells deeper than 500 feet
  - Drilling Permit good for 6 months, only
  - P&A/Site Restoration bond required before permit issuance

- New York State Environmental Quality Review (SEQRA)
  - Div. of Mineral Resources - Environmental Assessment Form (EAF) for Well Permitting - provides information about the physical setting of the proposed project, the general character of the land and land use, the projected size of the area that will be disturbed and the length of time the drilling rig will be on the site. Also details EAF the procedures that will be used to construct the access road, supply water for drilling, contain and dispose of wastes and reclaim the site. Information provided allows evaluation of the environmental impacts and site-specific concerns associated with the proposed drilling activity and determine whether special permit conditions, a Supplemental Environmental Impact Statement, or any additional permits are required.

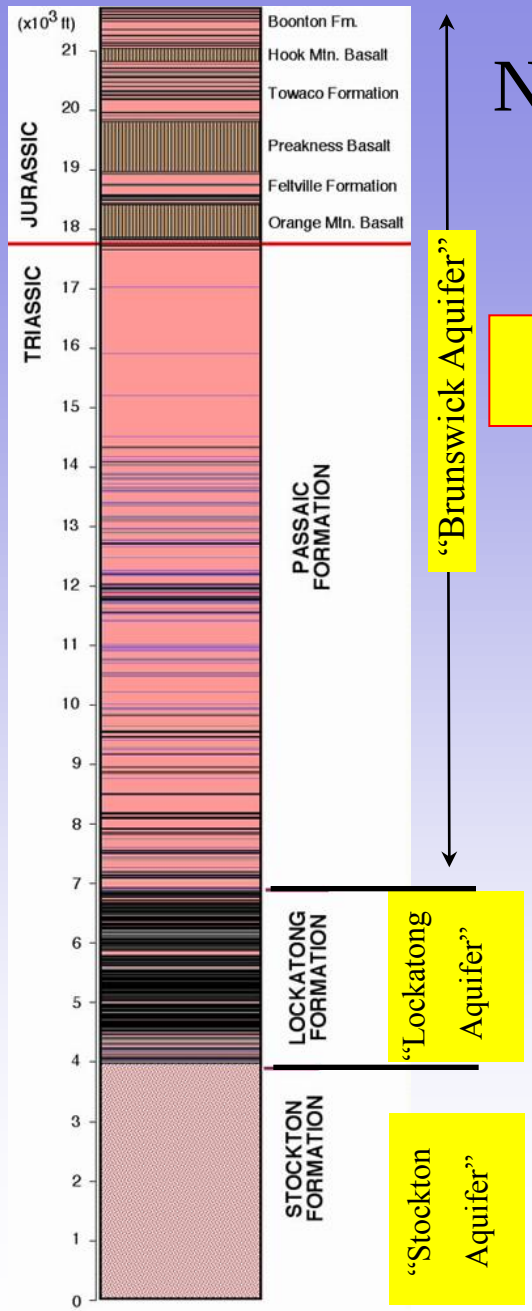
Task 1.4 – Compile Existing Data & Develop Geological Model

- Compile & Analyze Existing Data
- Develop GIS Database
- Develop Conceptual Geologic Model
- Review Conceptual Model w/Technical Team
- Produce 3-D Model Framework

Sources of Existing Basin Data

- Newark Basin Coring Project (7 wells (~3,500 feet deep), 4-inch diameter, in north-central New Jersey with 20,000 feet of core and geophysical logs)
- Lamont Doherty Earth Observatory (2 test wells ~1,200 feet deep penetrating through the Palisades Sill)
- Army Corp of Engineers - Passaic River Diversion Project Cores (lots of shallow cored wells)
- Two oil & gas exploration wells – mid-1980s (Pennsylvania)
- State and Federal GIS Database Information
- USGS, New Jersey and Pennsylvania Geological Survey Studies & Maps
- Geophysical Data (gravity, magnetics, limited seismic)

Newark Basin Stratigraphy



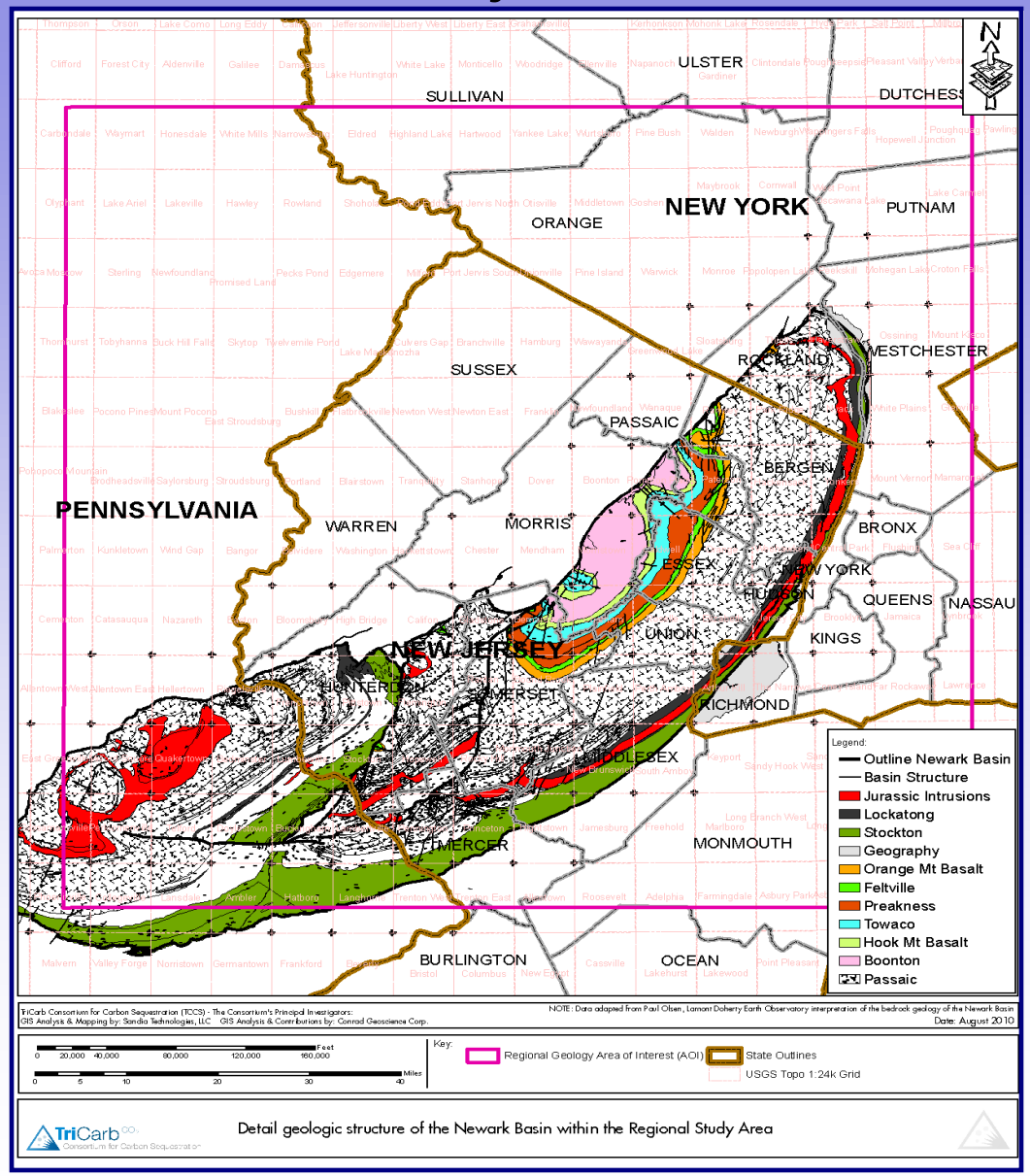
Playa lake and mudbank shales of the Passaic Fm provide secondary "seal" cap – up to 10,000 feet thick

Palisades Sill ~800 feet of diorite that "jumps" section

Deep lake and mudflat shales of the Lockatong Fm provide primary "seal" cap – up to 3,000 feet thick

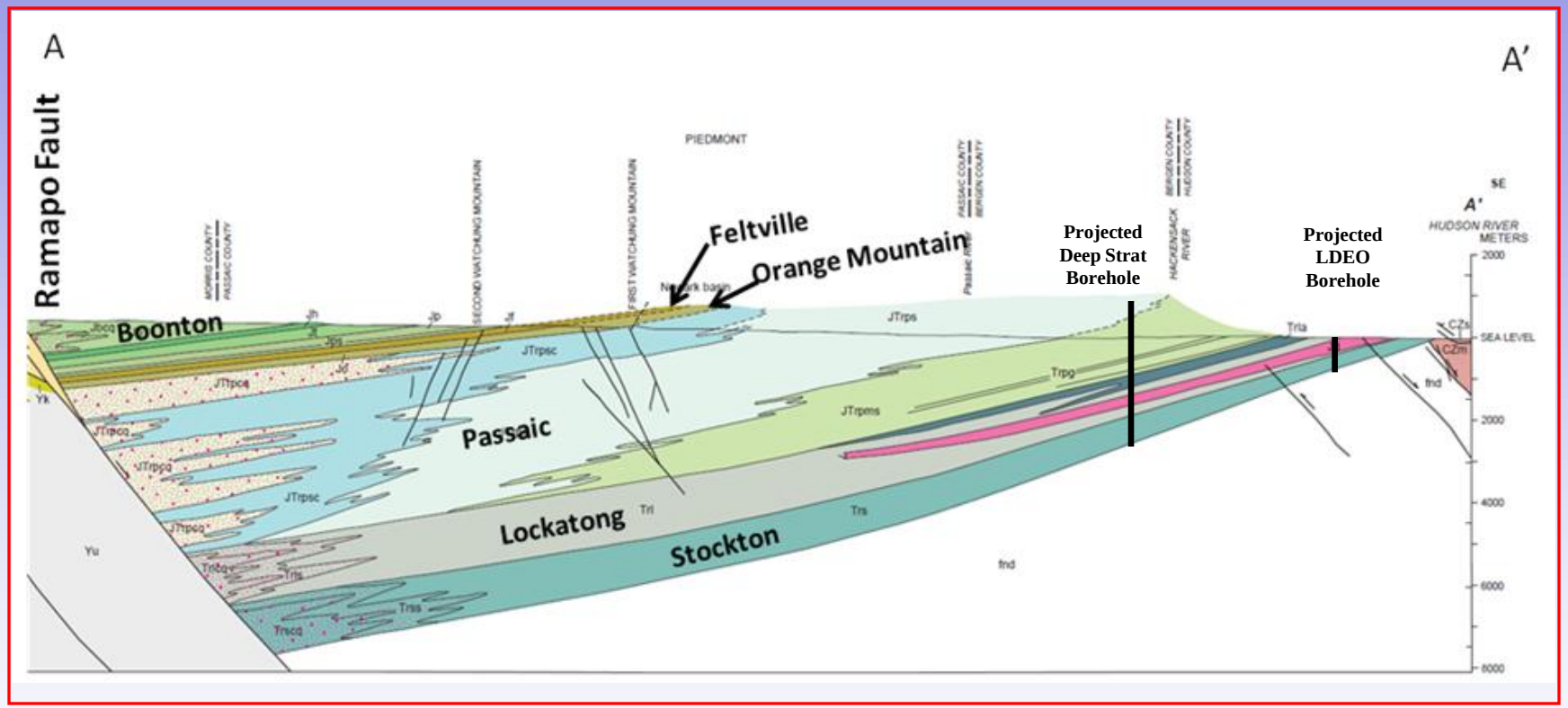
Target is fluvial-alluvial sandstones of the Stockton Fm – up to 6,000 feet thick (or more along border fault)

Geologic Map of the Newark Basin – Newark Basin Coring Project Data



from Paul Olsen Database

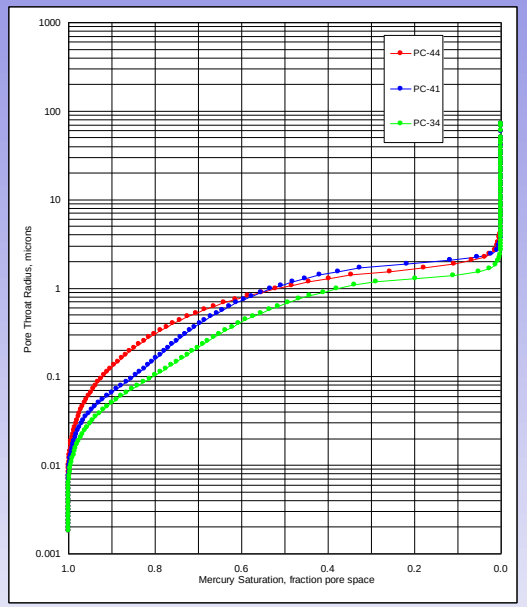
General Basin Cross Section – Northern New Jersey



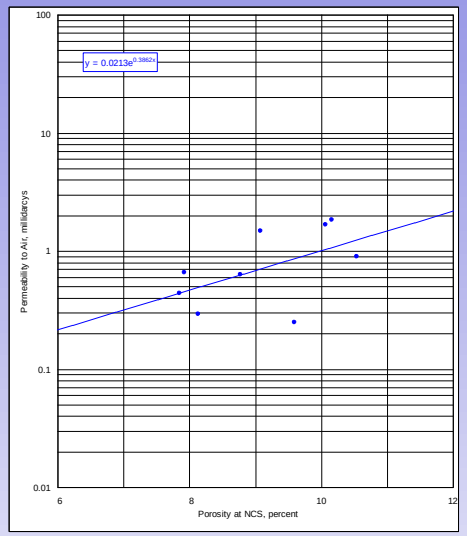
Open?

NBCP Princeton Well Core

Pore Throat Diameter



Porosity/Permeability



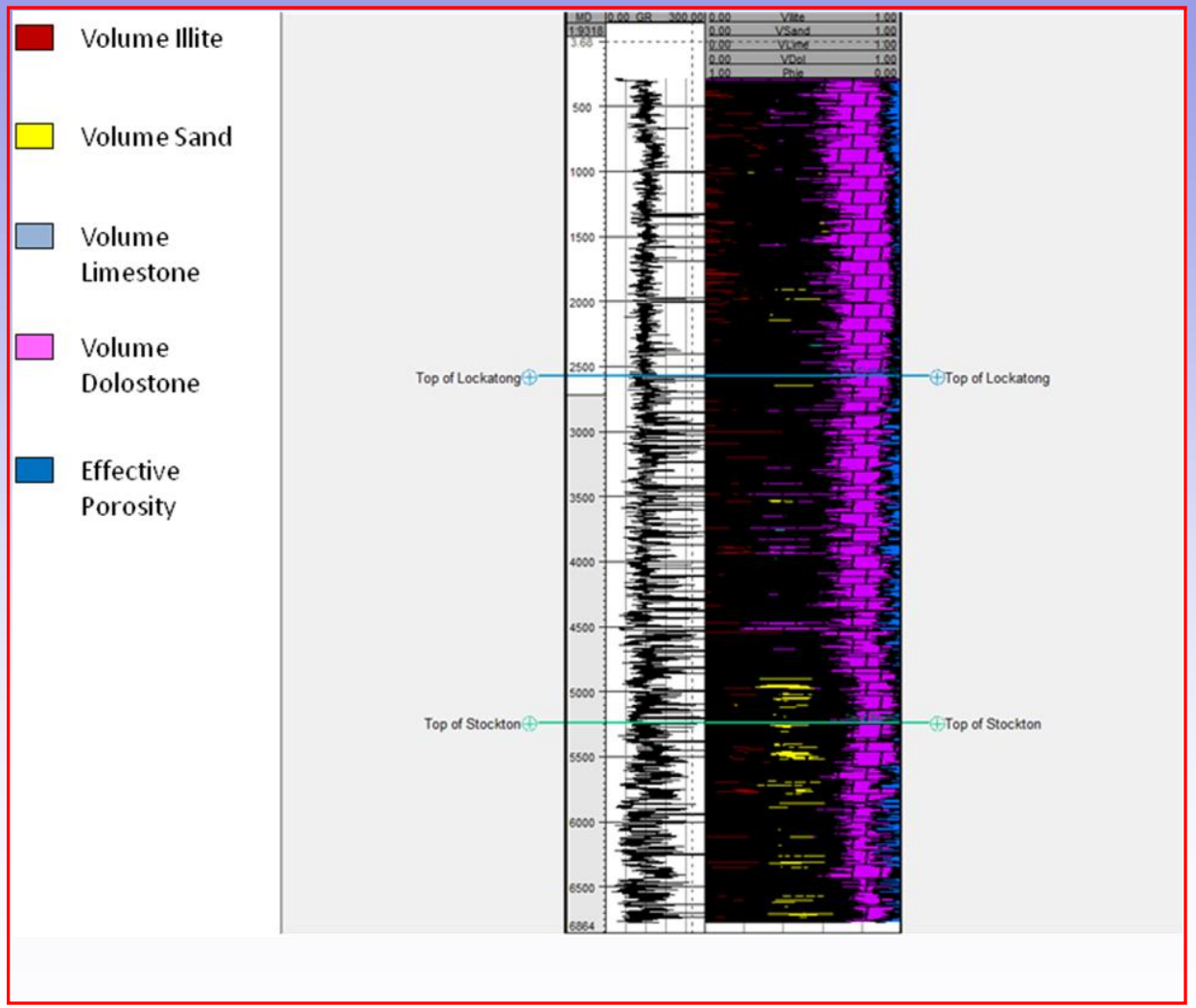
WEATHERFORD LABORATORIES
X-RAY DIFFRACTION
(WEIGHT %)

Client: **Sandia Technologies, LLC**
Well: **NBCP Princeton Core**
Area: **NJ, USA**
Sample Type: **Conventional Core**

Plug Number	Sample Depth (ft)	CLAYS				CARBONATES			OTHER MINERALS						TOTALS		
		Chlorite	Kaolinite	Illite	Mx I/S*	Calcite	Dolomite	Siderite	Quartz	K-spar	Plag.	Pyrite	Anhydrite	Hematite	Clays	Carb.	Other
PC-49	914.80	3	Tr	21	1	1	1	1	11	6	50	Tr	0	5	25	3	72
PC-47	1005.20	2	Tr	12	1	Tr	3	1	18	5	54	Tr	0	4	15	4	81
PC-43	1317.80	2	Tr	1	1	2	3	1	50	9	31	Tr	0	0	4	6	90
PC-41	1464.40	2	Tr	2	1	2	1	1	67	8	16	Tr	0	0	5	4	91
PC-28	1921.70	1	Tr	1	1	1	4	1	35	6	48	Tr	0	2	3	6	91
	AVERAGE	2	Tr	7	1	1	2	1	36	7	40	Tr	0	2	10	5	85

* Randomly interstratified mixed-layer illite/smectite; Approximately 90-95% expandable layers

Schlumberger Carbon Services Developed ELAN Composite Well Log from NBCP Wells



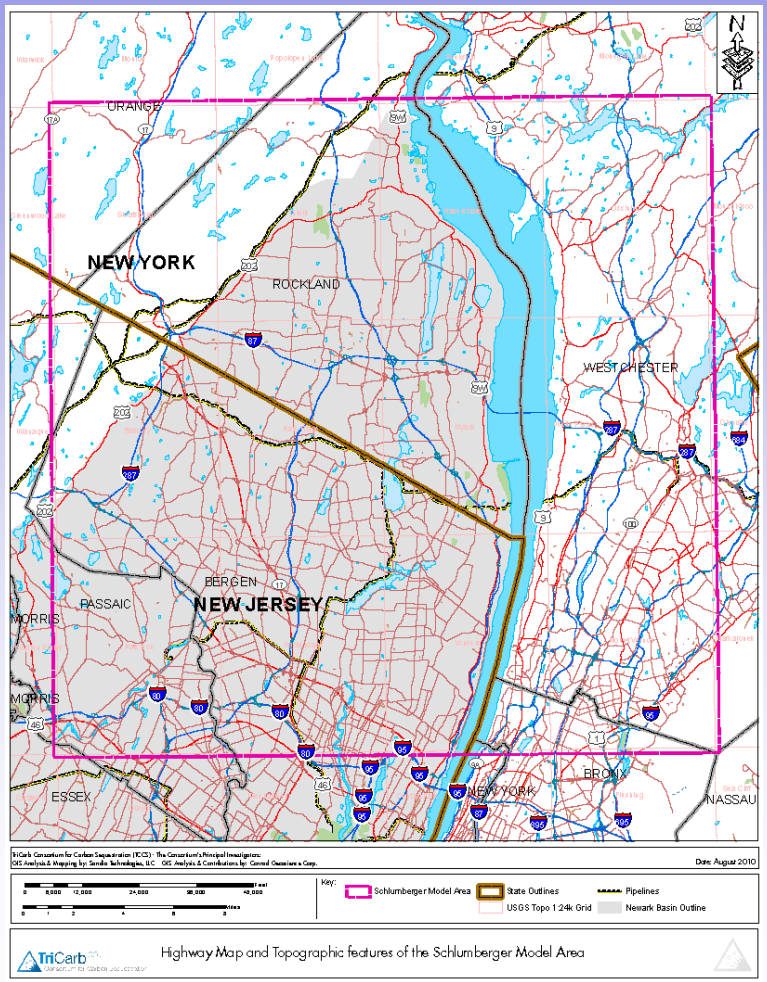
- Used overlapping NBCP well logs to compile and create a composite ~16,000-foot “type” well
- ELAN multi-mineral log analysis program computed the most probable formation mineralogy and pore volumes using a multi-log, least-squares inversion technique.
- Greatest percentage of sandstone is within the Stockton Formation and the bottom 400 feet of the Lockatong Formation, with an overall increase in porosity apparent approximately 340 feet below the top of the Stockton Formation

Developed GIS Database

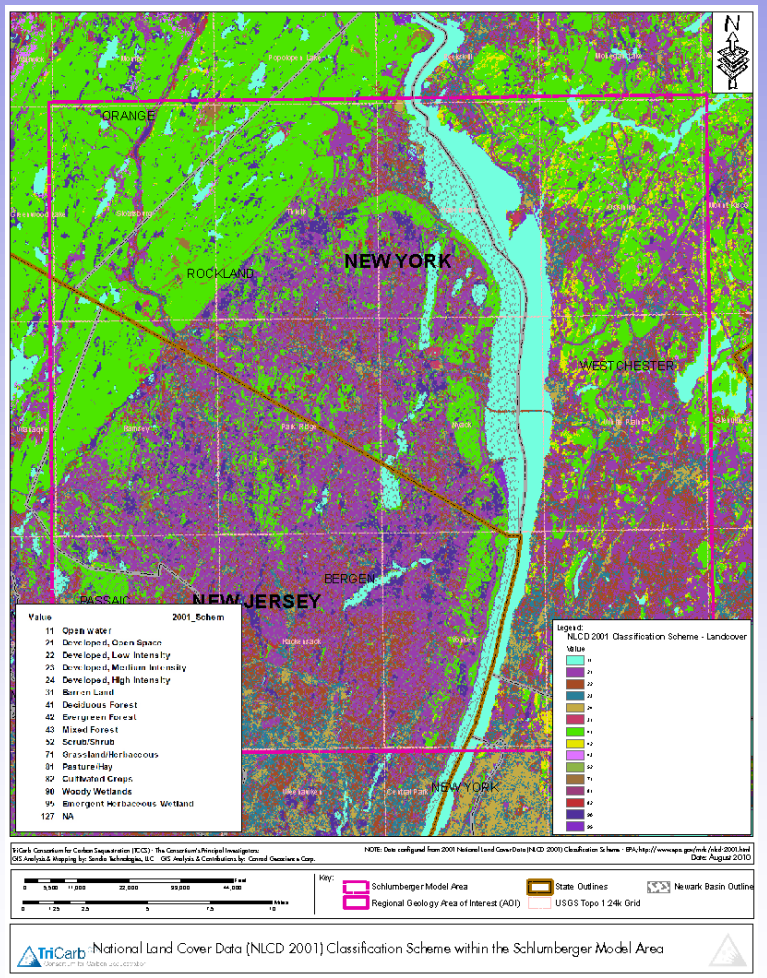
- Integrating data (land cover, topographic & photo-mosaic, stratigraphic, petrographic, structural, hydrologic, and water quality) into Geographic Information System (GIS) Database - ESRI
- Currently adding to www.tricarb.org website - Allows for easy access by interested parties
- To be integrated with NATCARB & MRCSP
- To be shared with project partners (NYS Museum, NJGS, LDEO)

Cultural/Landuse Details – Siting & Permitting

Highways

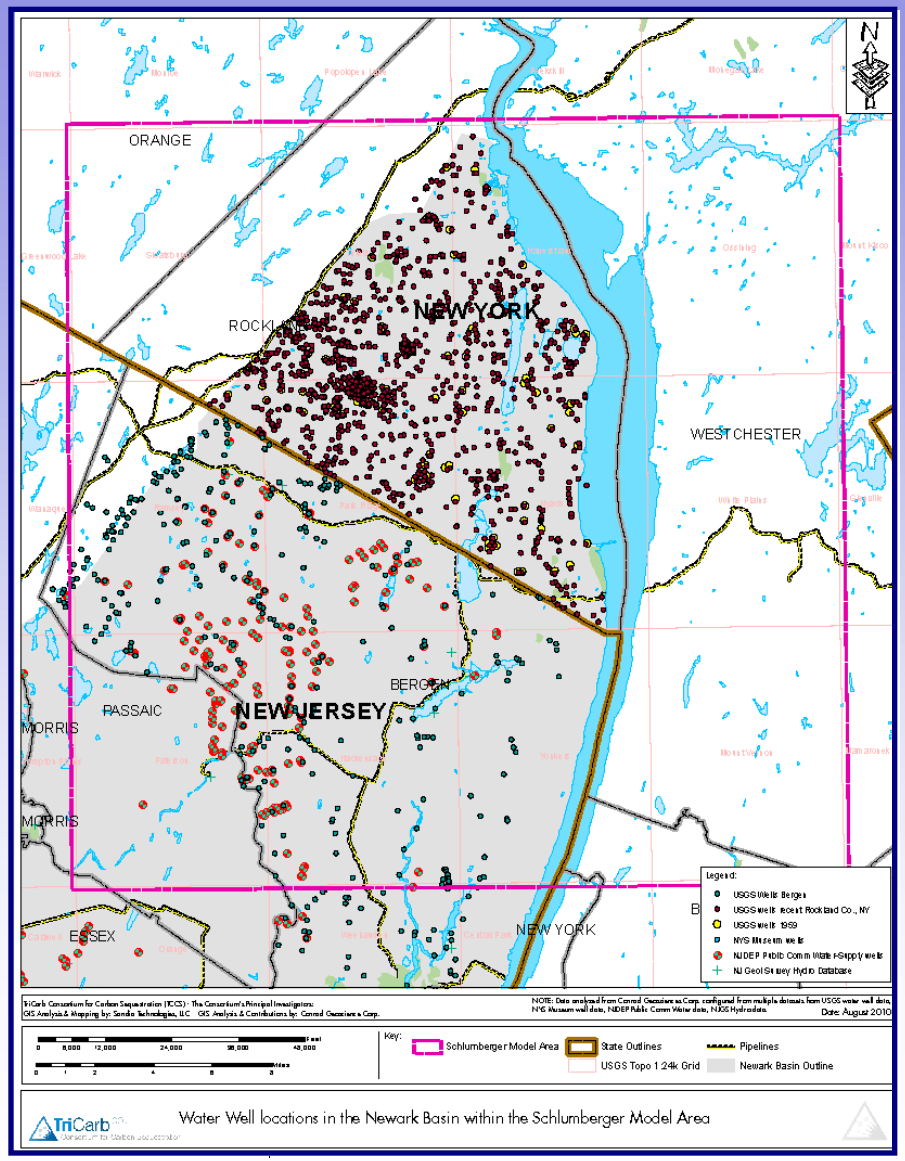


Land Cover

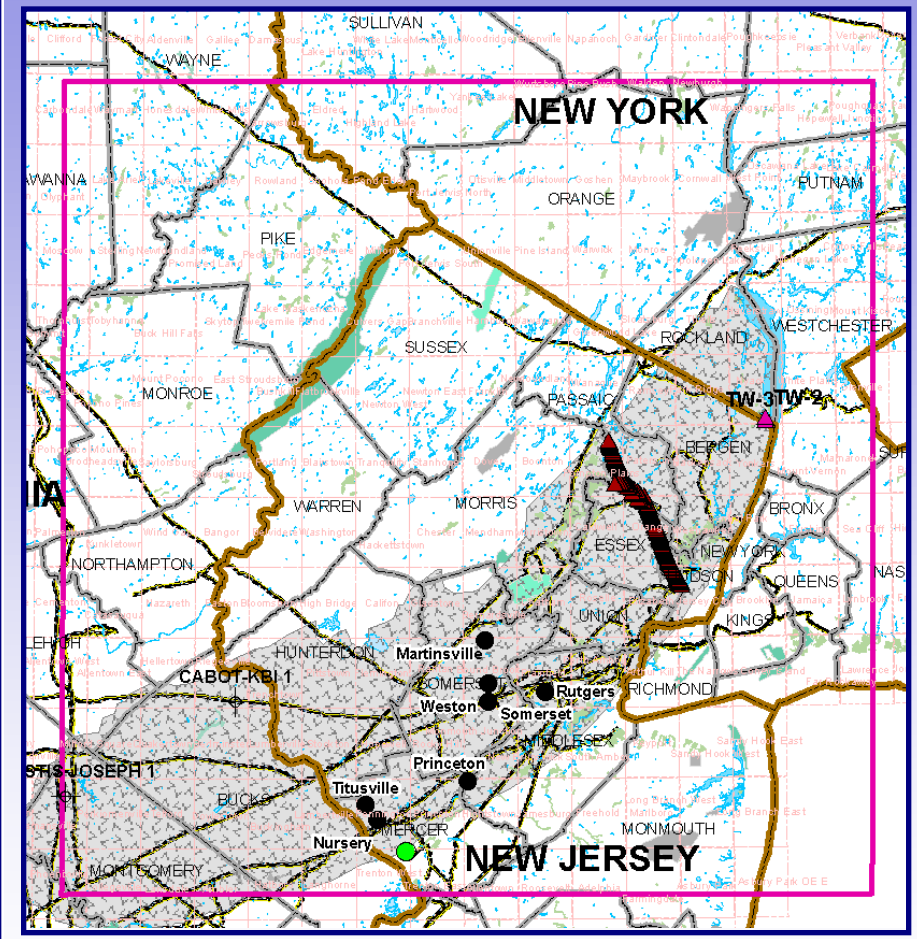


Well Data

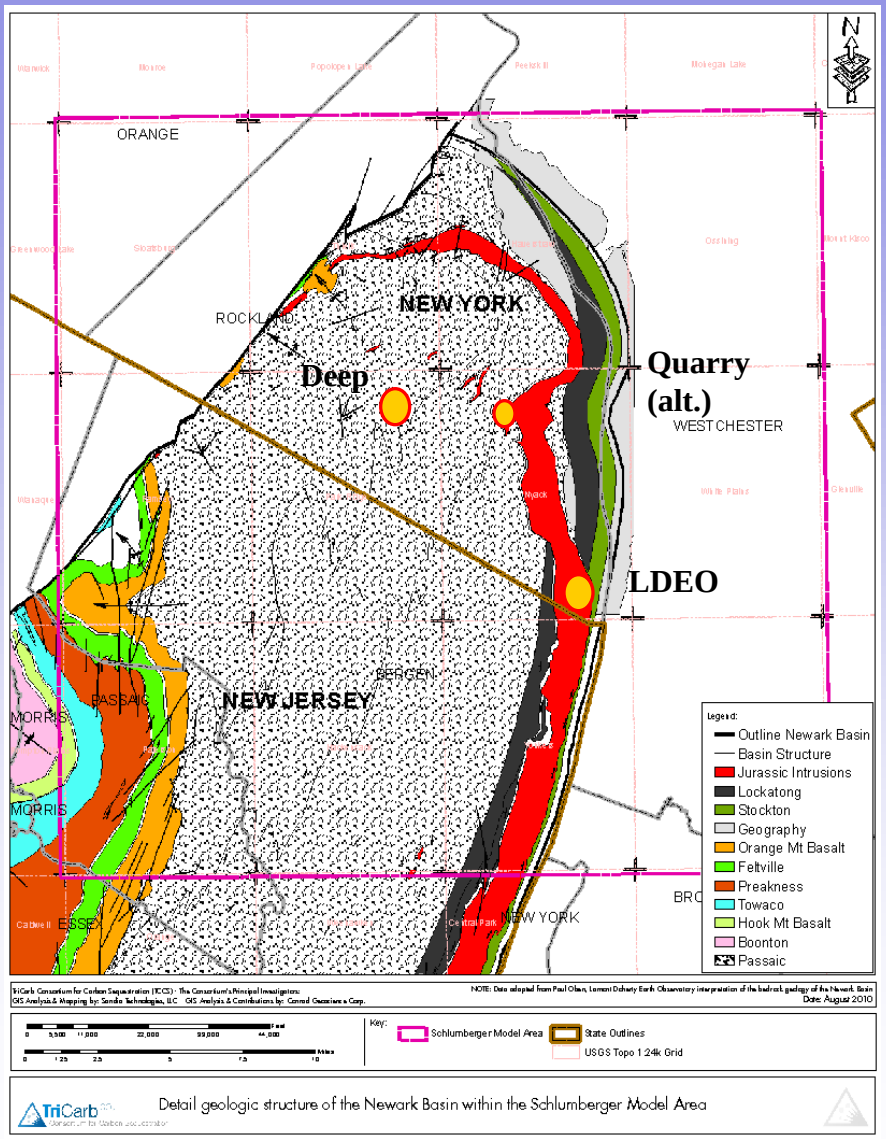
Water Wells



Geotechnical, Scientific & Oil/Gas Wells

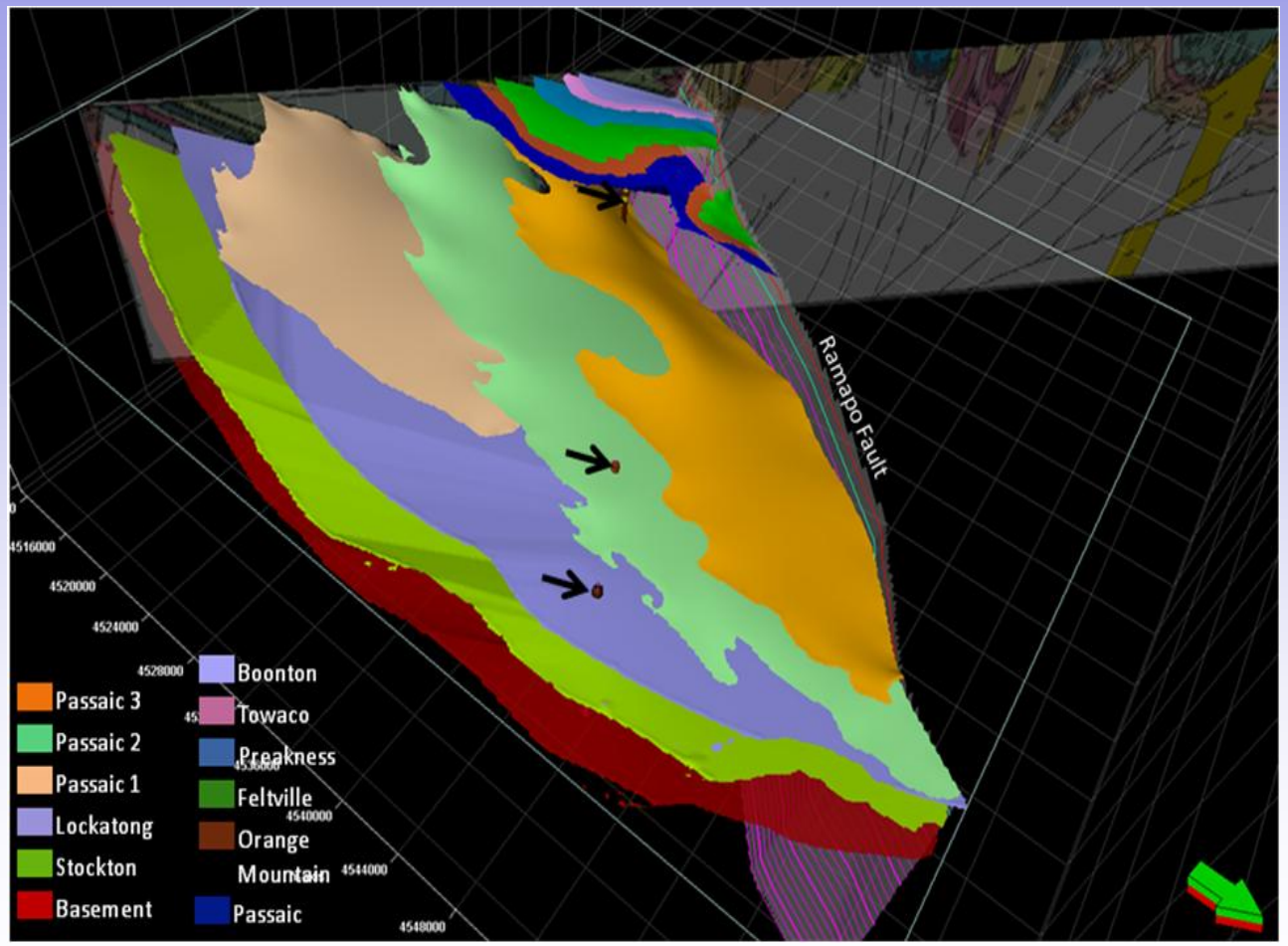


Bedrock Geology



- Geology from NBCP imported into GIS
- Cover of glacial sediments (50-100 ft) on top of bedrock in northern portion of the basin
- GIS Database allows for “quick look” assessments

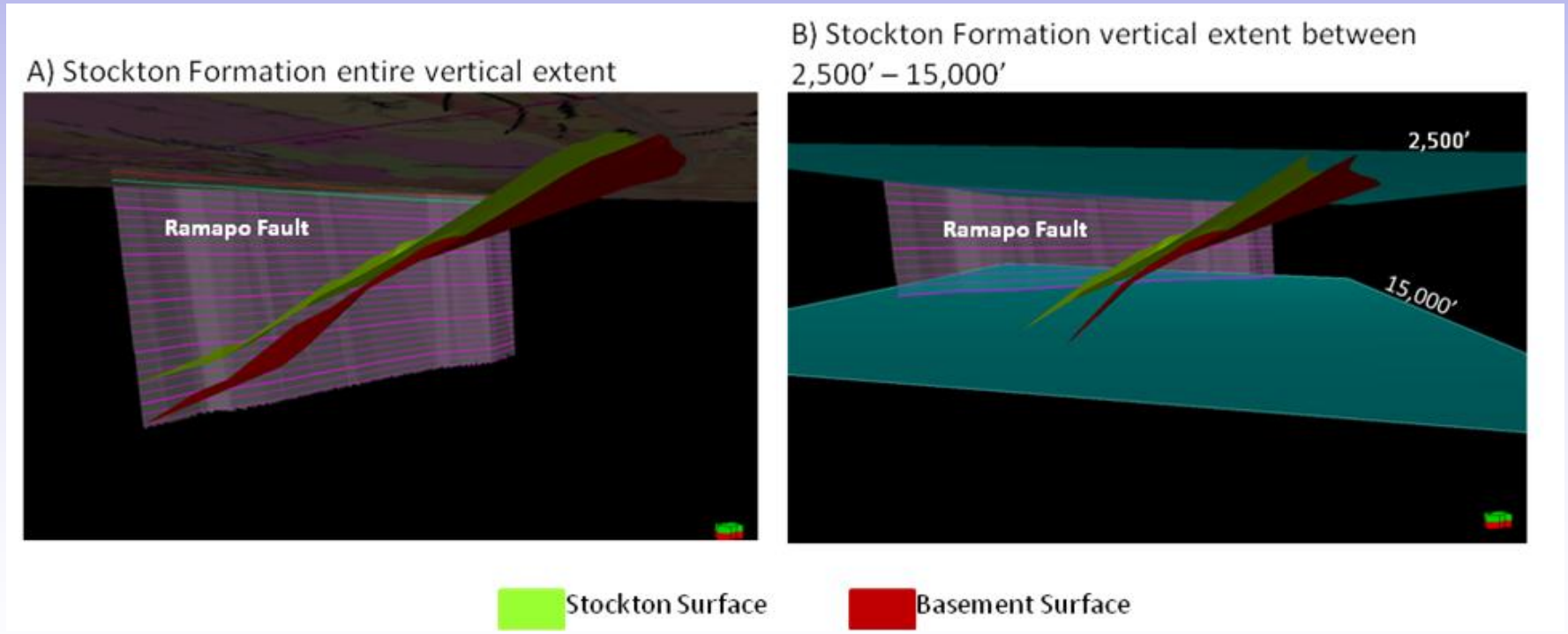
Schlumberger Carbon Services Developed Petrel 3-D Model Framework



- Developed predictive model surrounding the stratigraphic test well site(s) – using 16,000-ft "composite" well
- Use as illustrative tool for public outreach
- Basis for Phase II estimates of CO_2 storage capacity & modeling using Eclipse - for hypothetical injection scenarios

Early-look CO_2 Capacity Estimate

- Poor constraints on lateral variability (thickness, effective porosity, water quality, etc.) in Stockton Fm – Used a "simple dipping slab model
- Portions of the Stockton Fm are too shallow (<2,500 feet) and too deep (>15,000 feet) – rate of dip ~8º to 14º affects width of target area
- Volume of Stockton Fm between these two depths defines the "Sequestration Window"



Basin Pressure/Temperature Models

Pressure Model ~ Fresh Water Gradient?

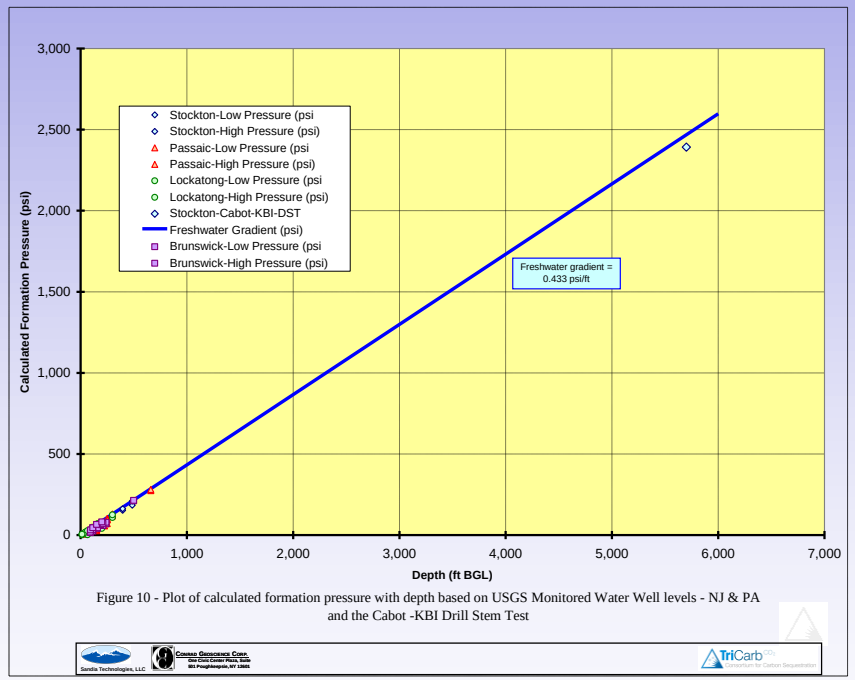


Figure 10 - Plot of calculated formation pressure with depth based on USGS Monitored Water Well levels - NJ & PA and the Cabot -KBI Drill Stem Test

NBCP Measured Temperature Gradients

^{o}C/Km

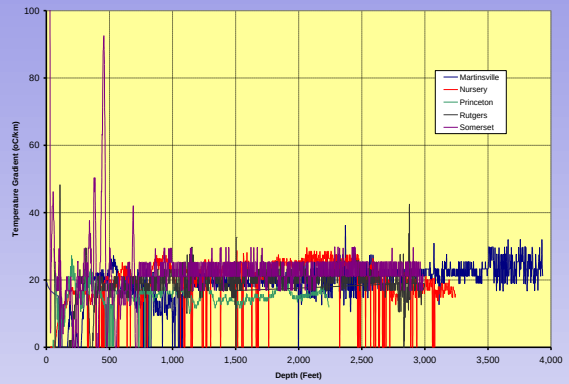


Figure 7 - Plot of measured subsurface temperature gradients with depth in select Newark Basin Coring Project wells

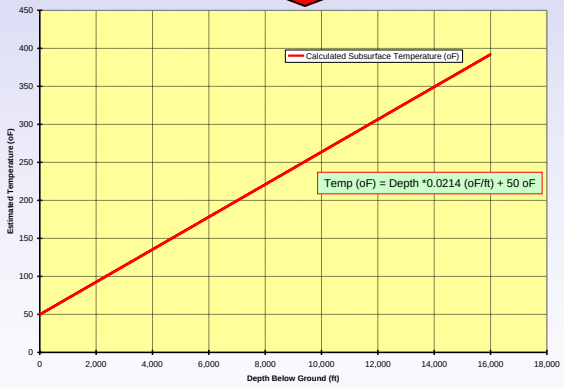
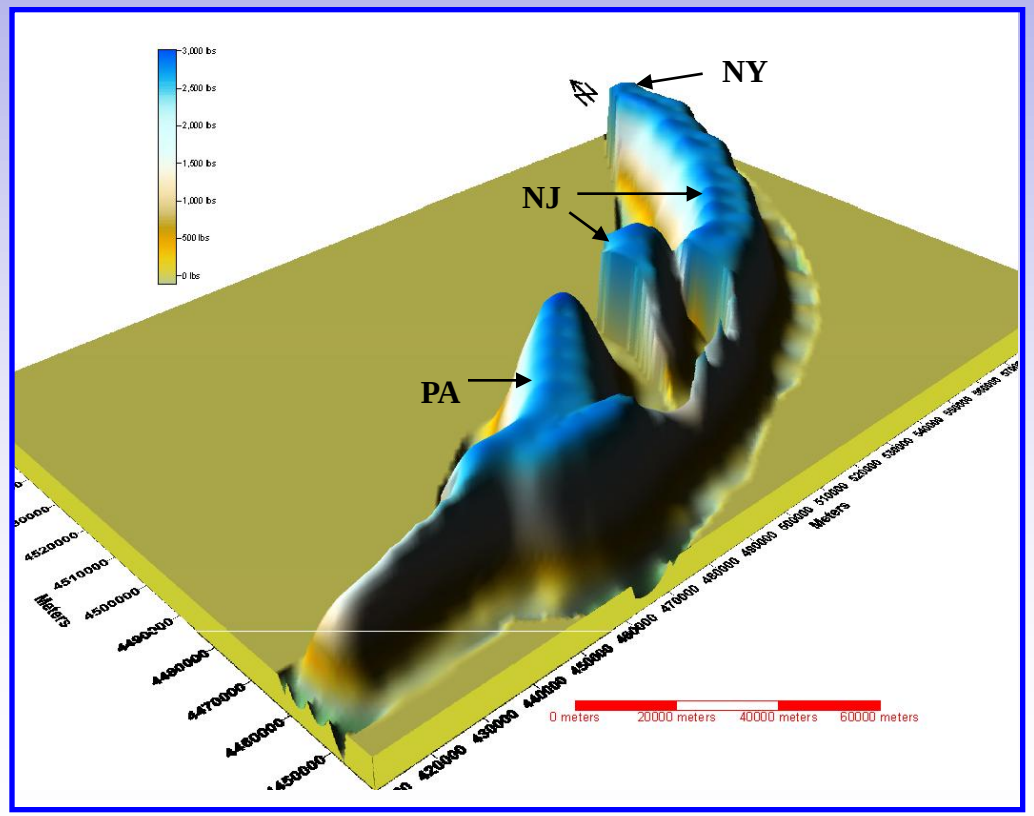


Figure 8 - Plot of calculated subsurface temperature with depth in the Newark Basin

Temperature = 2.14 ^{o}F/100ft + 50 ^{o}F

Early-look CO_2 Capacity Estimate-Continued

- Pressure/Temperature profiles with depth used to calculate CO_2 density/solubility in Stockton Fm.
- NBCP Princeton Well used as “type section” for net/gross ratio and average porosity
- Estimated capacity for Stockton Fm ~1 Gigatonne (20% storage area)



Key Phase I Deliverables

- Documentation that all permits/approvals secured and well drilling operations may proceed (finalizing access for deep stratigraphic borehole site and NYSDEC stratigraphic test well permits)
- Topical report discussing the GIS Database, Conceptual Basin Model/3-D Visualization Model, and CO_2 Capacity Assessment (final once GIS Database portion added – this month)

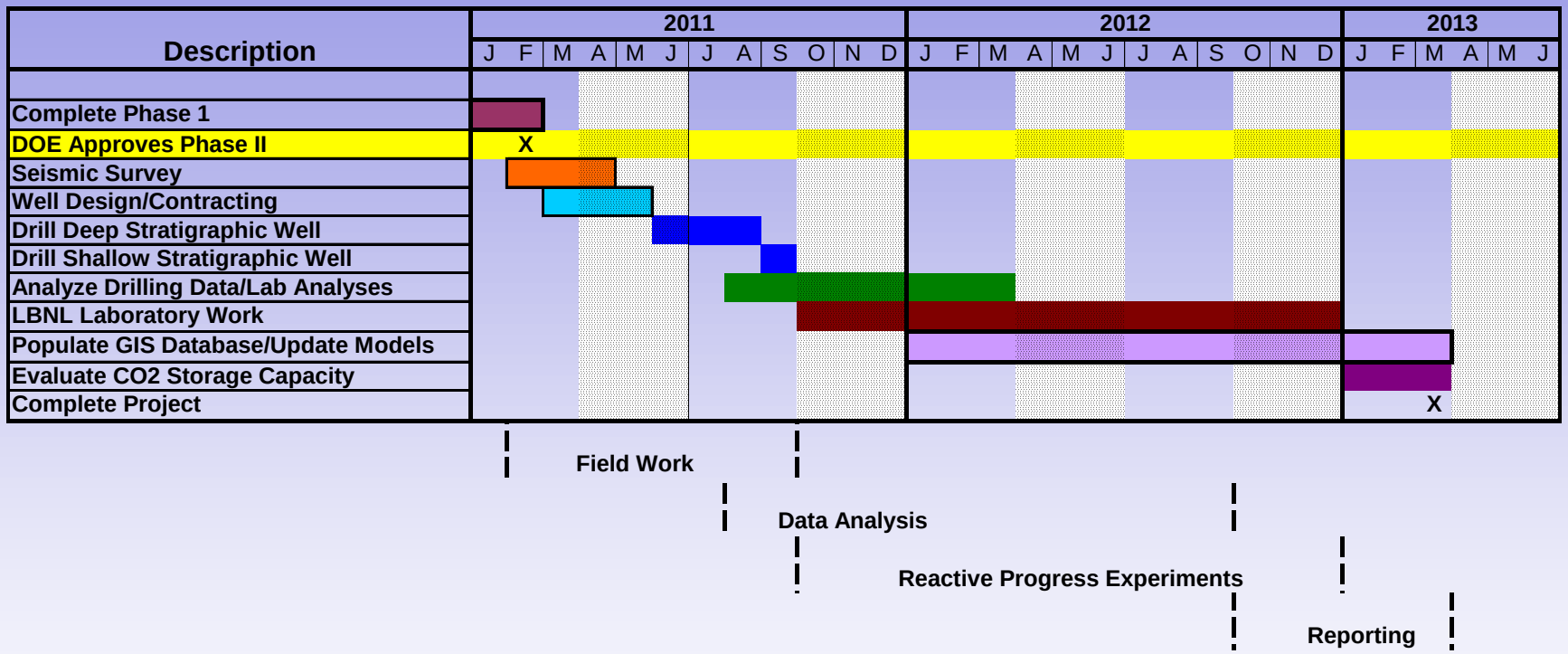
Path Forward
Phase 2 – Field Implementation & Data Analysis

- Task 2.1 – Project Management & Planning
- Task 2.2 – Seismic Survey
- Task 2.3 – Final Well Design
- Task 2.4 – Test Well Subcontractors
- Task 2.5 – Site Preparation, Drill and Acquire Hydrogeological Data in Deep Stratigraphic Well

Phase 2 – Field Implementation & Data Analysis (Continued)

- Task 2.6 – Review and Analyze Hydrogeological Data and Prepare Reports
- Task 2.7 – Update Models
- Task 2.8 – Evaluate CO_2 Storage Capacity and Prepare Report
- Task 2.9 – Develop Recommendations for Further Investigation or Well Abandonment
- Task 2.10 – Contingency for Well Abandonment

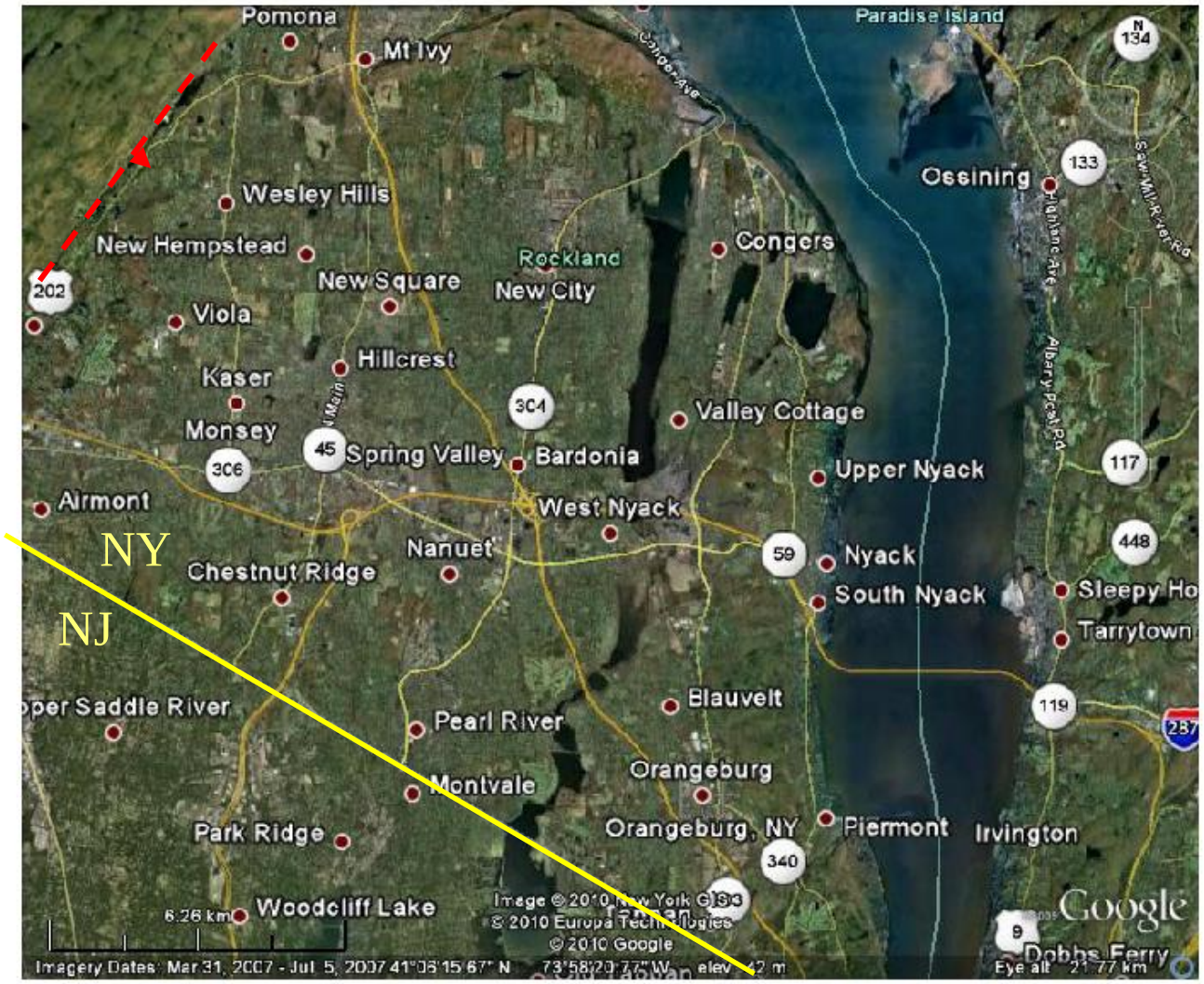
Project Schedule-Extended Project



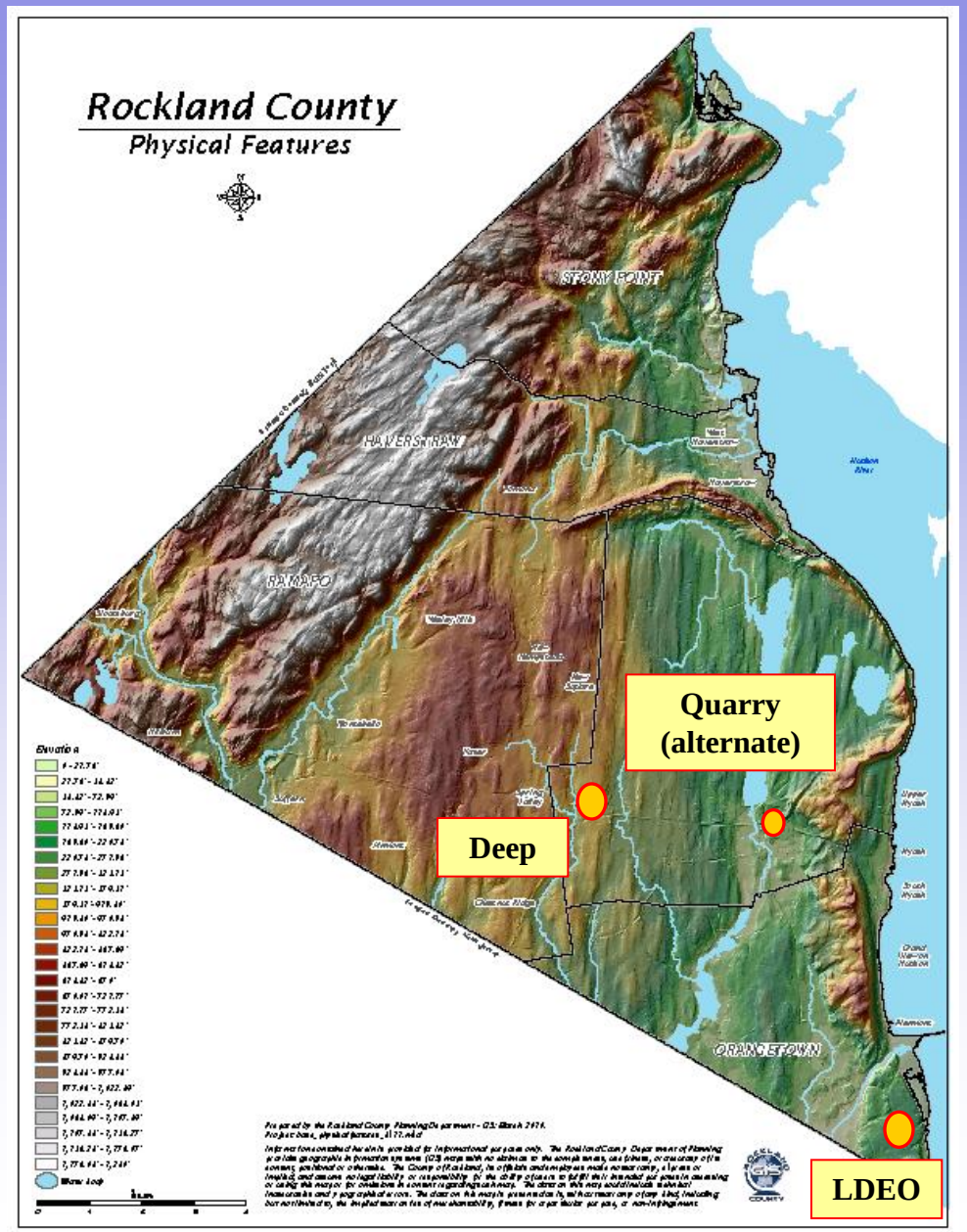
Task 2.2 – Seismic Survey

- Plan includes two crossing 2-D seismic lines approximately crossing at deep test site
- Project Extension adds line length
- Glacial cover & Palisades Sill may pose an "imaging" problem (i.e. want to "see" below the sill)
- Lack of local velocity information
- Field work will be in an urbanized environment

Project Located in an Urbanized Area



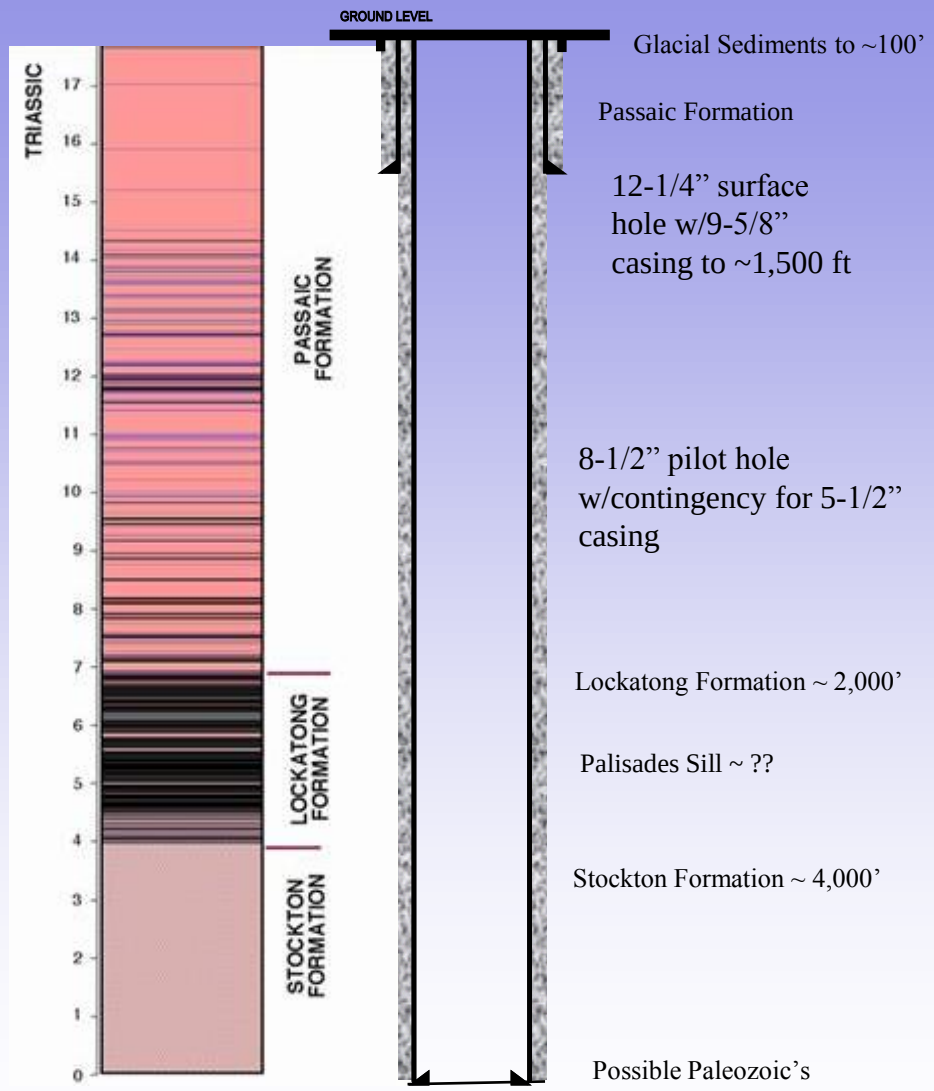
Newark Basin in Rockland County, New York



- Ramapo Fault forms the western border fault
- General dip is to the west-northwest, towards the border fault (~8 to 12 degrees).
- Deep Stratigraphic Well expected to be ~8,000 ft TVD
- LDEO well expected to be ~2,000 ft TVD
- Quarry (alternate location) is expected to be ~4,000 ft TVD

Task 2.5 – Deep Stratigraphic Borehole

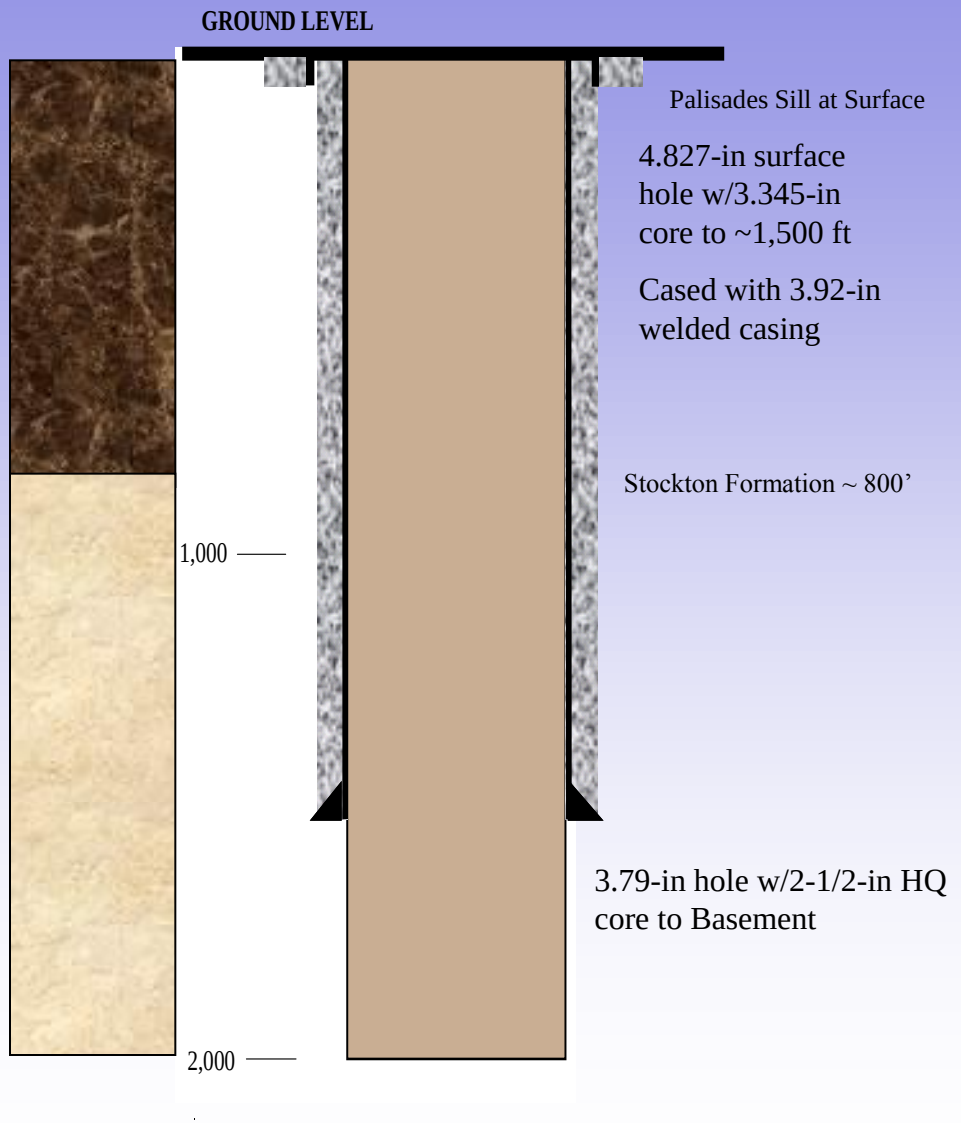
Strategy is a Deep Borehole to Sedimentary Basement



- Evaluate shallow groundwater zones
- Protect freshwater zones behind Surface Casing
- 8-1/2-inch pilot hole to total depth, possible Paleozoic sediments below basin
- Maximize whole core in borehole to tie into Newark Basin Coring Project and calibrate logging suite
- Maximize open hole logging to provide comprehensive "type log" suite
- Recover formation fluids to define hydrostratigraphy
- Potential aquifer tests to define transmissivity & flow characteristics (drill stem and/or pump tests)
- No Injection Planned!! (would need a UIC Permit)

Task 2.5 – Slim-hole Mineral Core Hole

Strategy is a Borehole to Sedimentary Basement Near Outcrop



PTD Up to 2,000 feet

- Protect utilized freshwater zones behind Surface Casing
- Maximize whole core in borehole from top to bottom
- Slim-hole open hole logging program to provide comprehensive "type log" suite
- Measure formation pressures to define hydrostratigraphy
- Potential aquifer tests to define transmissivity & flow characteristics (LDEO)

Task 2.5 – Continuous Wireline Coring

Deep Well - NOV Corion Express®

- Equipment integrates onto existing O&G rig
- PDC Bit drills/cores 8-1/2-in hole with 3-in diameter core
- Can alternate coring or drilling w/o pulling drill string
- Wireline core retrieval w/o pulling/redressing drill string

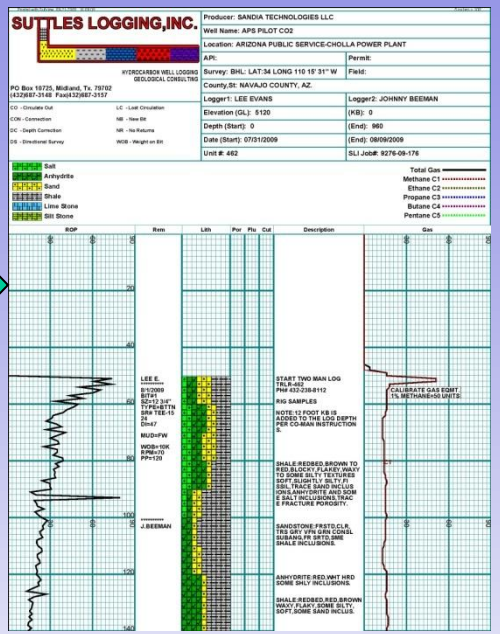
Task 2.5 – Enhanced Open Hole Logging
Deep Stratigraphic Test Well

- Standard Logging Suite
  - Platform Express
  - Elemental Capture
  - Formation Micro-imager (Deep)
  - Magnetic Resonance (Deep)
  - Mechanical Rotary Cores
  - Drill Stem Testing
- Enhanced Logging Suite
  - Surface Hole Formation Micro-imager
  - Surface Hole Magnetic Resonance
  - Modular Dynamics Tester
  - Full Sonic Scanner Acoustical Logging
  - Vertical Seismic Profile

Field Evaluation Methodologies

Whole Core

Well Cuttings Analysis



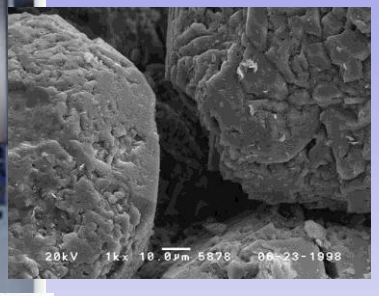
Open-hole Logging

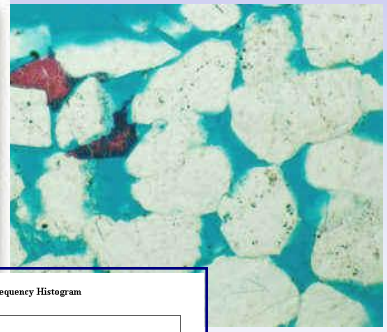
Fluids Recovery

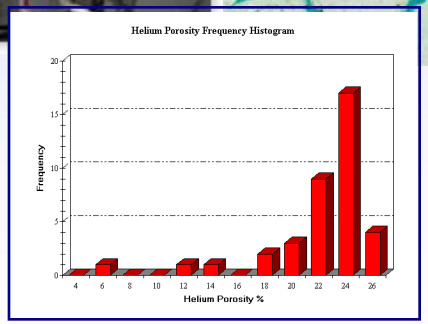
Task 2.6 – Review and Analyze Hydrogeological Data and Prepare Reports

Analyze Hydrogeological Data

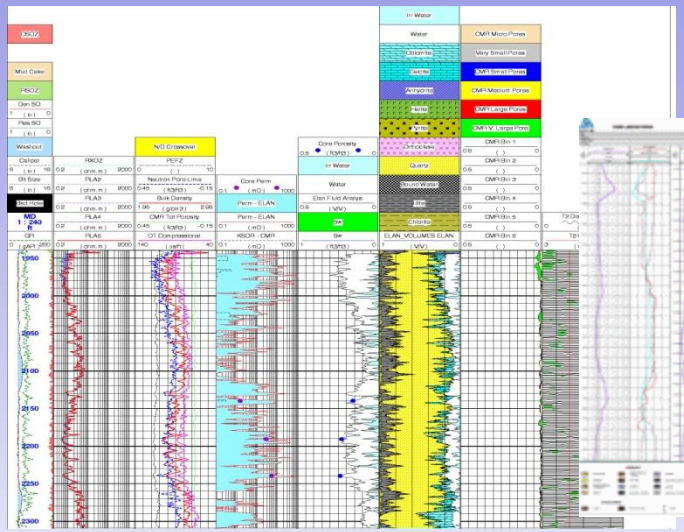
Core

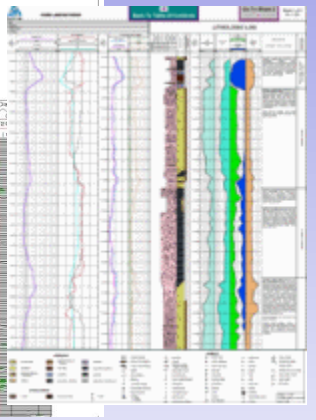




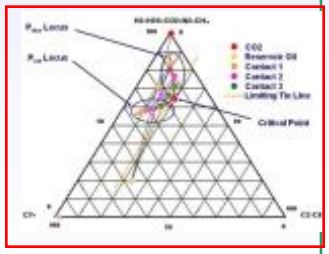


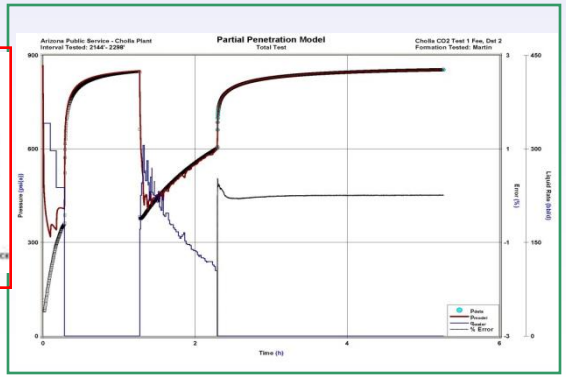
Well Log Analyses



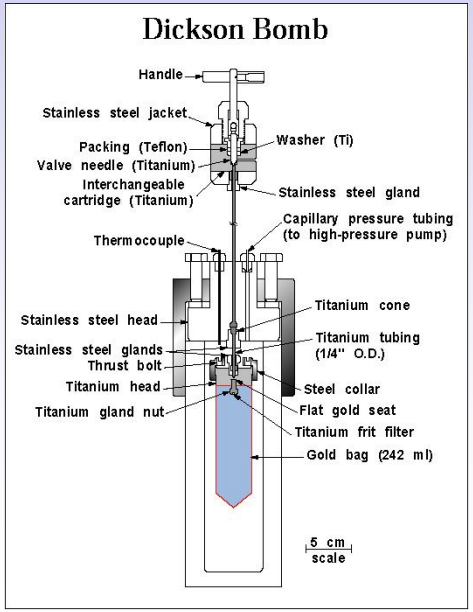


Formation Fluid and Aquifer Properties



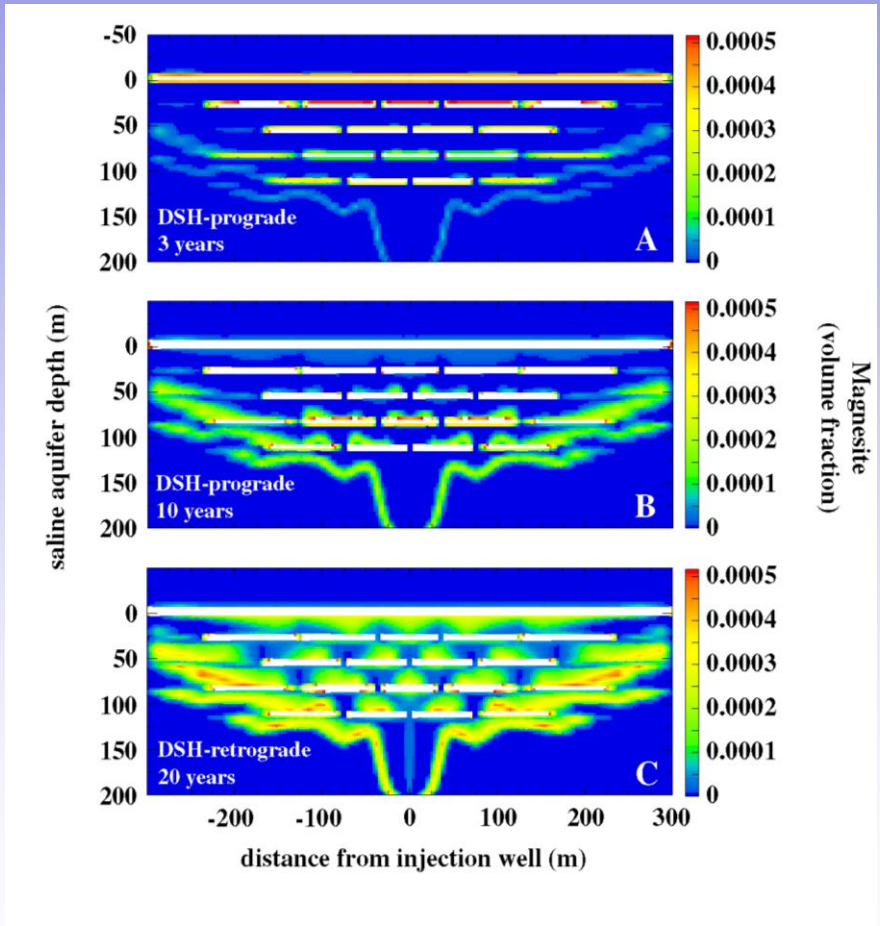


Task 2.7 – Update Models/ Task 2.8 – Evaluate CO_2 Storage Capacity/ Reactive Transport



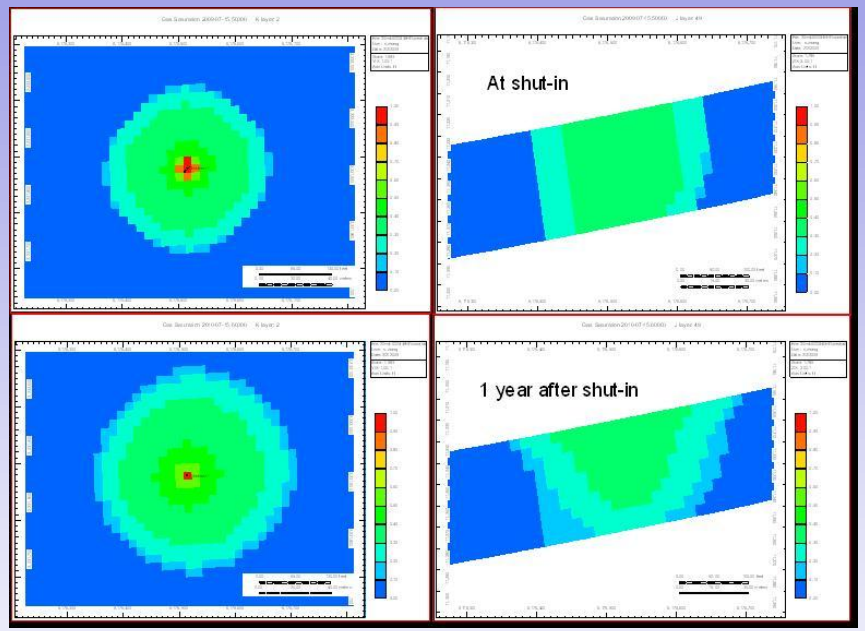
- Lawrence Berkeley to investigate experimentally the interactions of CO_2 with rock matrix and formation fluids (K Knauss)
- Assess rate of CO_2 dissolution into the formation brine and mineralization in the formation materials
- Reactive progress experiments will take approximately one year to run

Task 2.7 – Update Models/ Task 2.8 – Evaluate CO_2 Storage Capacity/ Reactive Transport



- Lawrence Berkeley to then take well data results (pressure/temperature/ compositions), combined with the experimentally measured reactive progress data to prepare fate model (TOUGHREACT) for injecting CO_2 into the Newark Basin

Task 2.7 – Update Models/
Task 2.8 – Evaluate CO_2 Storage Capacity
Flow Simulations



- Revaluate petrophysical properties and basin conceptualization used in Phase 1 Petrel Model
- Perform basin-scale "what if" flow simulations in Eclipse for hypothetical point sources to assess response to industrial-scale injection scenarios
- Refined assessment of injection capacity for CO_2 in the Newark Basin

Phase II Deliverables

- Topical report and description of Seismic Survey
- Final Well Plans for site preparation, well installation, and testing
- Summary of Vendor Recommendations Report
- Relevant Properties of the Borehole and Target Formations Report
- CO_2 Storage Capacity Report
- Final Well Abandonment Plans for well closure and site restoration
- Well Closure & Site Restoration Report

Questions?